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ATMOSPHERIC PHYSICS

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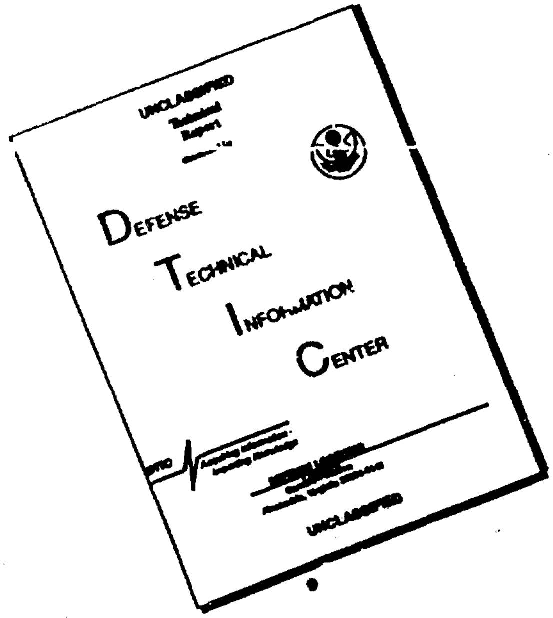

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Possible Identification of

Volcanic Dust

in the Stratosphere*

by

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Atmospheric Physics

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Abstract:

Balloon soundings of the atmospheric aerosol made at three different latitu confirm the existence of a widespread dust layer over the Northern Hemisphere. Soundings made at Minneapolis over a period of five years show seasonal fluctuations in the total stratospheric dust by as much as a factor of four with a suggestion of a secular decrease from 1963 to 1968. Soundings made at Panama show a decrease of the dust by a factor of ten from 1966 to 1968. This rapid decrease in the amount of the equatorial dust is not inconsistent with the estimated rates of dilution and dispersion of radioactive bomb debris by horizontal and vertical eddy motion. The spectrum of particle size of the Panama aerosol is considerably flatter than that of the mid-latitude aerosol, indicating they may be of different origin. It is suggested that these additional equatorial particles are the residue of volcanic material injected into the stratosphere in the Bali explosion of 1963. A more definitive measurement of the aerosol spectrum at mid-latitude shows a slope only slightly flatter than that reported by Junge in 1961 but with considerably greater concentration of particles larger than 1μ. This could be caused by an increase in the number of large particles after the Bali event or a loss of large volatile particles counted by filter methods.

A number of stratospheric dust soundings have been made at sporadic intervals starting a few months after the Bali eruption in March of 1963 (Rosen 1964, 1966, 1968). The detector employed was a balloon borne photoelectric particle counter and was sensitive to sizes a few tenths of microns in diameter and larger. The soundings were made over Panama (10°N), Minneapolis (45°N) and Churchill (60°N) and indicated a dense stratospheric dust belt over the tropical tropopause as the world-wide source of dust. In order to confirm the existence of this dust belt in the tropical stratosphere, another set of soundings were made over Panama in April of 1968. Figure 1 is a comparison of the results and shows that the dust concentration dropped by more than a factor of 10 to a value more comparable to the concentrations observed at higher latitudes (see Figure 2). Figure 3 shows that the size distribution of the stratospheric dust also changed considerably and became more typical of that observed at higher latitudes (Rosen 1968). The fact that the dust concentration over Panama in September of 1966 was apparently unusually high and the size distribution of this dust was considerably different from all other dust soundings, indicates that this dust was not from the same source as the normal stratospheric dust. This conclusion strongly suggests that the dust observed over Panama in September, 1966 was a result of the Bali eruption of March 1963.

Since the stratospheric residence time is about 10 months (Krey, 1967), the dust concentration in the time between the two sets of soundings over Panama would be expected to decrease by about a factor of 4 if the dust were of volcanic origin. The observed factor of 10 decrease indicates that the dust associated with the high particle concentration found on the first set of Panama soundings has perhaps moved south of the equator and relatively cleaner air has taken its place. Figure 4 also indicates that the dust

associated with the first set of Panama soundings is not completely gone from the tropical stratosphere. These two soundings were made about six hours apart and indicate an intrusion of dust above 30 mb with an unusually steep size distribution. Thus the increased dust concentration above 30 mb observed in the second flight can perhaps be associated with the dust found over Panama in September of 1966.

The decrease in the high latitude stratospheric dust since the Bali eruption is shown in Figure 5. The rate of decrease is consistent with the removal rate of radioactive debris, but shows large variations from the average. It also appears from Figure 5 that the stratospheric dust concentration at 45°N has almost returned to its pre-eruption value. If this implication is correct, then the dust concentration in the northern hemisphere must have increased by about an average factor of 2 or 3 after the Bali eruption. Several more years of measurement with the photoelectric particle counter would be needed to satisfactorily assess the undisturbed stratospheric dust concentration.

Direct collection of stratospheric dust has indicated that the particles were somewhat volatile (Junge et al. 1961; Mossop 1963). This property of the dust was also demonstrated with the photoelectric particle counter. The sampled air was heated before the dust particles were counted, so that if the dust tended to vaporize the counting rate would decrease. The results are shown in Figure 6 and indicate that the particles can be partially destroyed by heating the intake air above 70° centigrade at 17 mb. The accompanying change in the size distribution also indicates that the heat changed the physical nature of the particles. Under controlled laboratory conditions, using an aerosol made of particles with a boiling point of 90°C at 17 mb, very similar results were obtained.

APPENDIX

The size spectrum of the stratospheric aerosole at mid-latitude.

The photoelectric particle counter measures the total number of particles with a maximum diameter greater than some pre-assigned value. In its present form there are two channels which simultaneously measure the particle concentration for two settings of the minimum size particle detected. By making a second sounding with a different setting of the discriminator level it is possible to construct a more definitive size spectrum for the aerosole (assuming that the spectrum remained constant during this interval). The cumulative size distribution resulting from two such flights at Minneapolis is shown in Figure 7. This plot is the logarithm of the particle concentration over the cutoff diameter setting and is seen to fit a straight line of the form $N = N_o \exp(-4r)$ where N_o is 3 particles cm^{-3} and r is the radius of the particle in microns.

Junge, et al. (1961) and others have reported a power law size spectrum of the form assumed in calculating the size parameter, α. The slope of the present exponential spectrum is quite similar to Junge's for particles less than .2μ radius, but shows a considerably greater concentration of the very large particles. Since these observations were made almost a decade after Junge's, the additional large particles may too represent a change in the stratospheric dust after the Bali explosion. But in view of the volatile nature of the aerosole reported above, it is also likely that filter methods which expose the particles to a large air flow may lose some particles by evaporation.

References

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Figure 1. The vertical distribution of large aerosols (>.2μ) over Panama in 1966 and 1968. The concentration in 1968 is so much smaller it cannot satisfactorily be shown on the same scale (see also Figure 2).

Figure 2. A comparison of representative dust profiles at three latitudes. The sounding for 10° latitude is the same 1968 sounding at Panama shown in Figure 1. The particle concentrations shown on this later sounding in the tropics are quite similar to the concentrations normally observed in at northern latitudes.

Figure 3. The profile of the size distribution parameter α for the Panama soundings in 1966 and 1968. The cumulative size distribution is assumed to have the form $N \sim r^{-\alpha}$ and is determined from total particle counts at two values of r, the particle radius.

Figure 4. The size parameter α for two Panama soundings made only six hours apart.

Figure 5. Time variation of the total concentration of large stratospheric particles at 45°N. The smooth curve shows the expected change in particle concentration for a stratosphere residence time of 10 months.

Figure 6. The variation in stratospheric particle count as the intake air is heated. This observation was made at 17 mb (28 km) over Panama in 1968.

Figure 7. The apparent cumulative size distribution of stratospheric dust at 45°N.

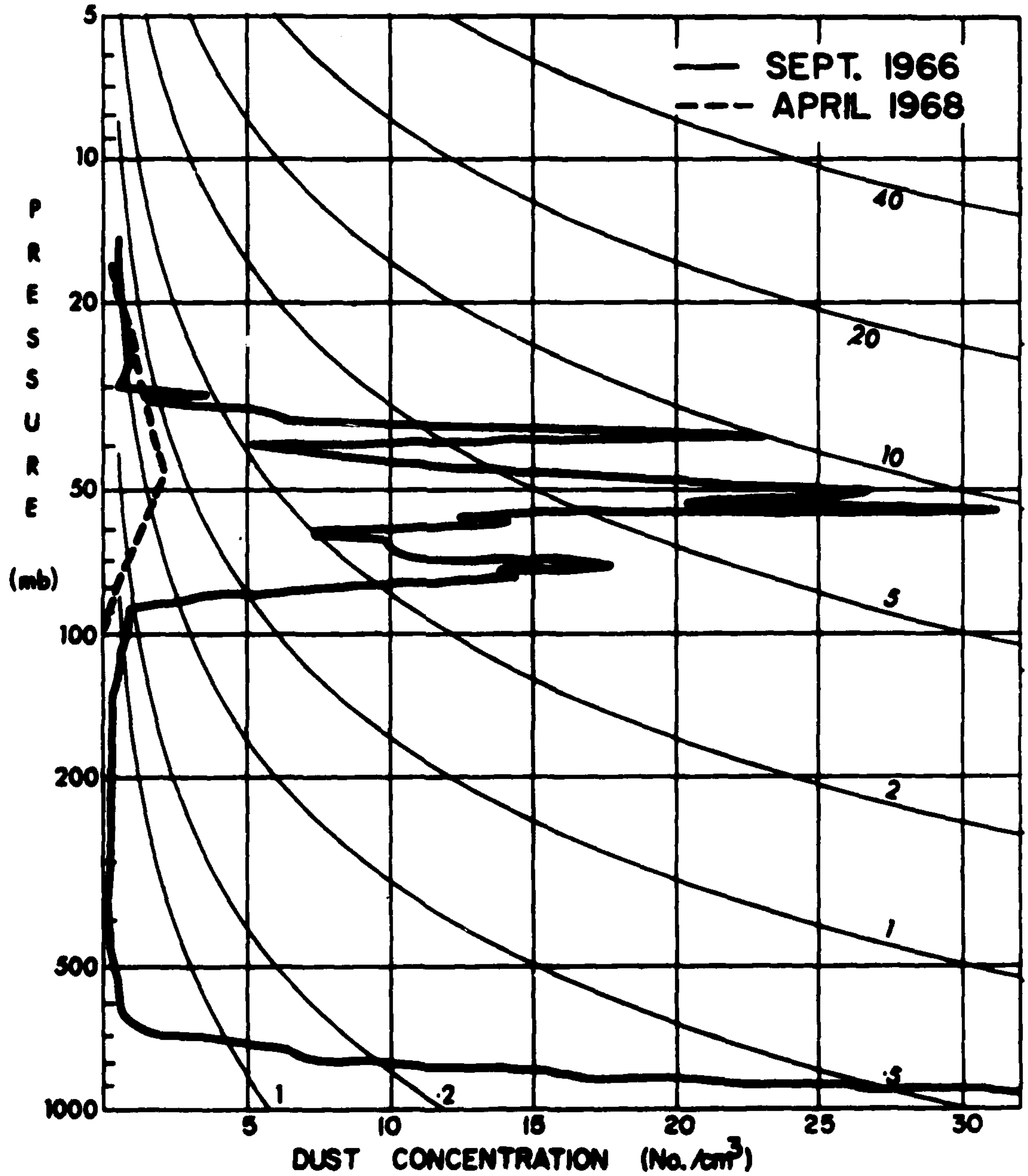
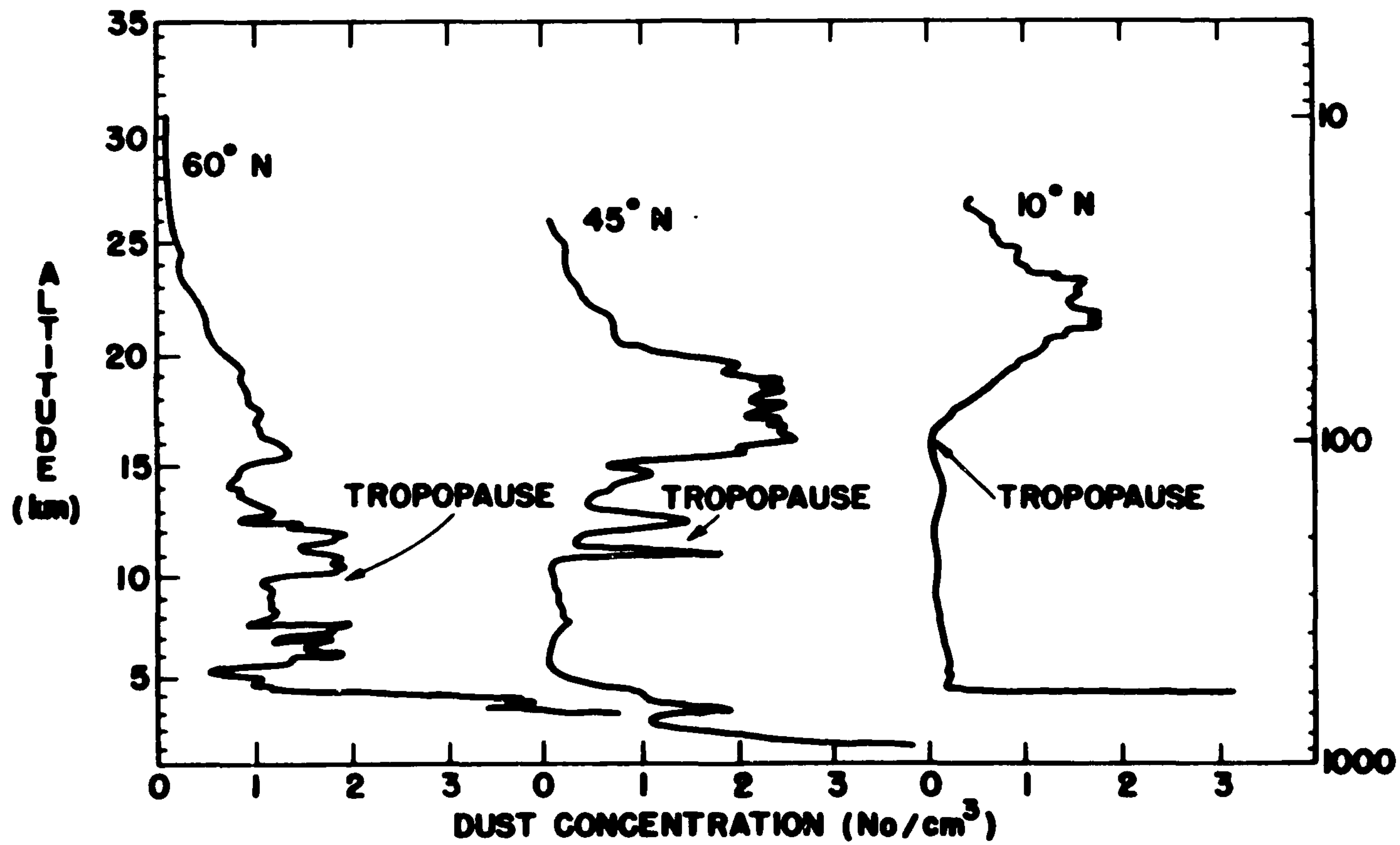
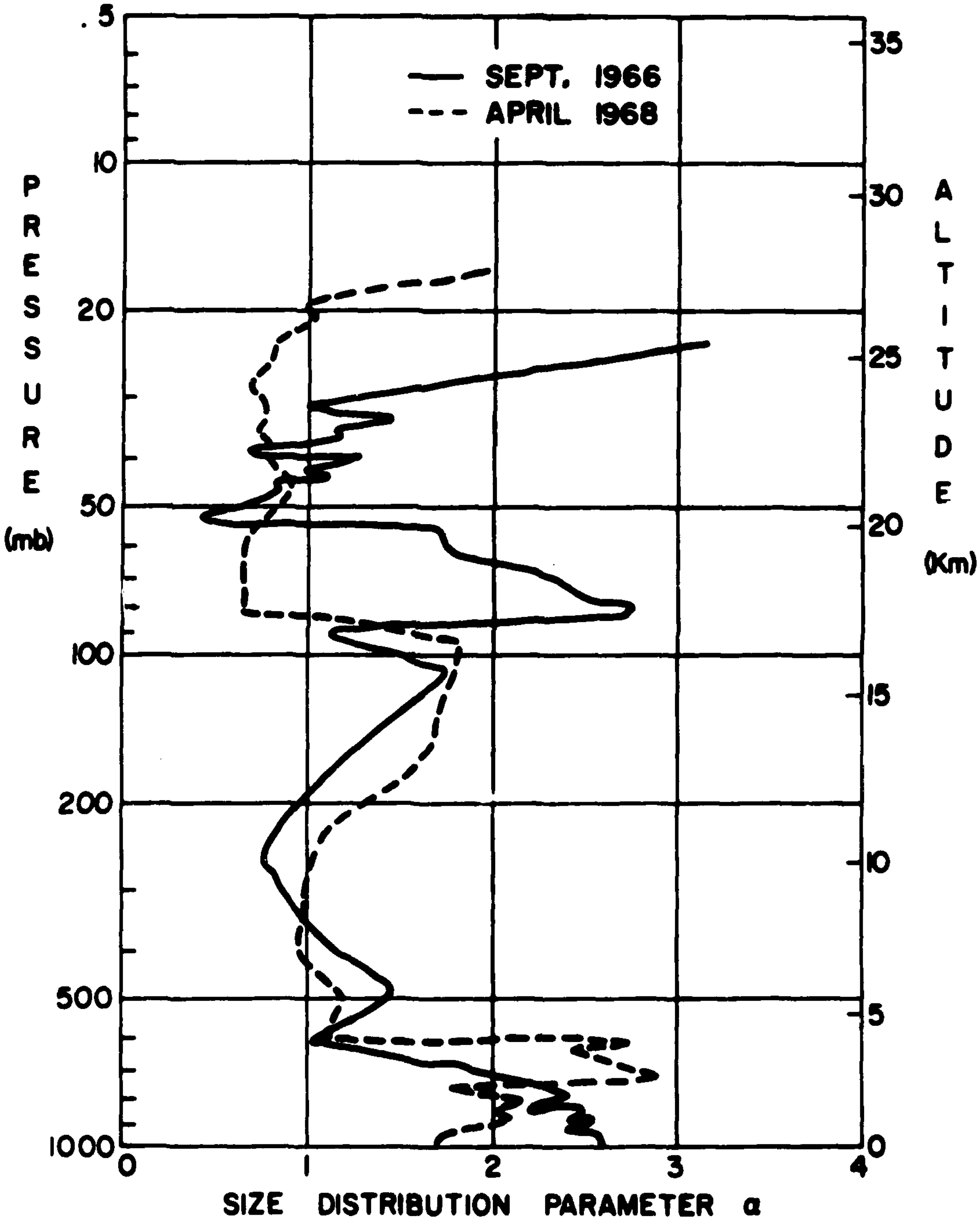

SEPT. 1966
APRIL 1968
PRESSURE
(mb)
5
10
20
50
100
200
500
1000
40
20
10
5
2
1
.5
1
.2
5
10
15
20
25
30
DUST CONCENTRATION (No./cm³)

Figure 1



35
30
25
20
15
10
5
ALTITUDE (km)
60° N
45° N
10° N
TROPOPAUSE
TROPOPAUSE
TROPOPAUSE
10
100
1000
PRESSURE (mb)
0 1 2 3 0 1 2 3 0 1 2 3
DUST CONCENTRATION (No/cm3)

Figure 2



SEPT. 1966
APRIL 1968
PRESSURE (mb)
.5
10
20
50
100
200
500
1000
ALTITUDE (Km)
35
30
25
20
15
10
5
0
0
1
2
3
4
SIZE DISTRIBUTION PARAMETER α

Figure 3

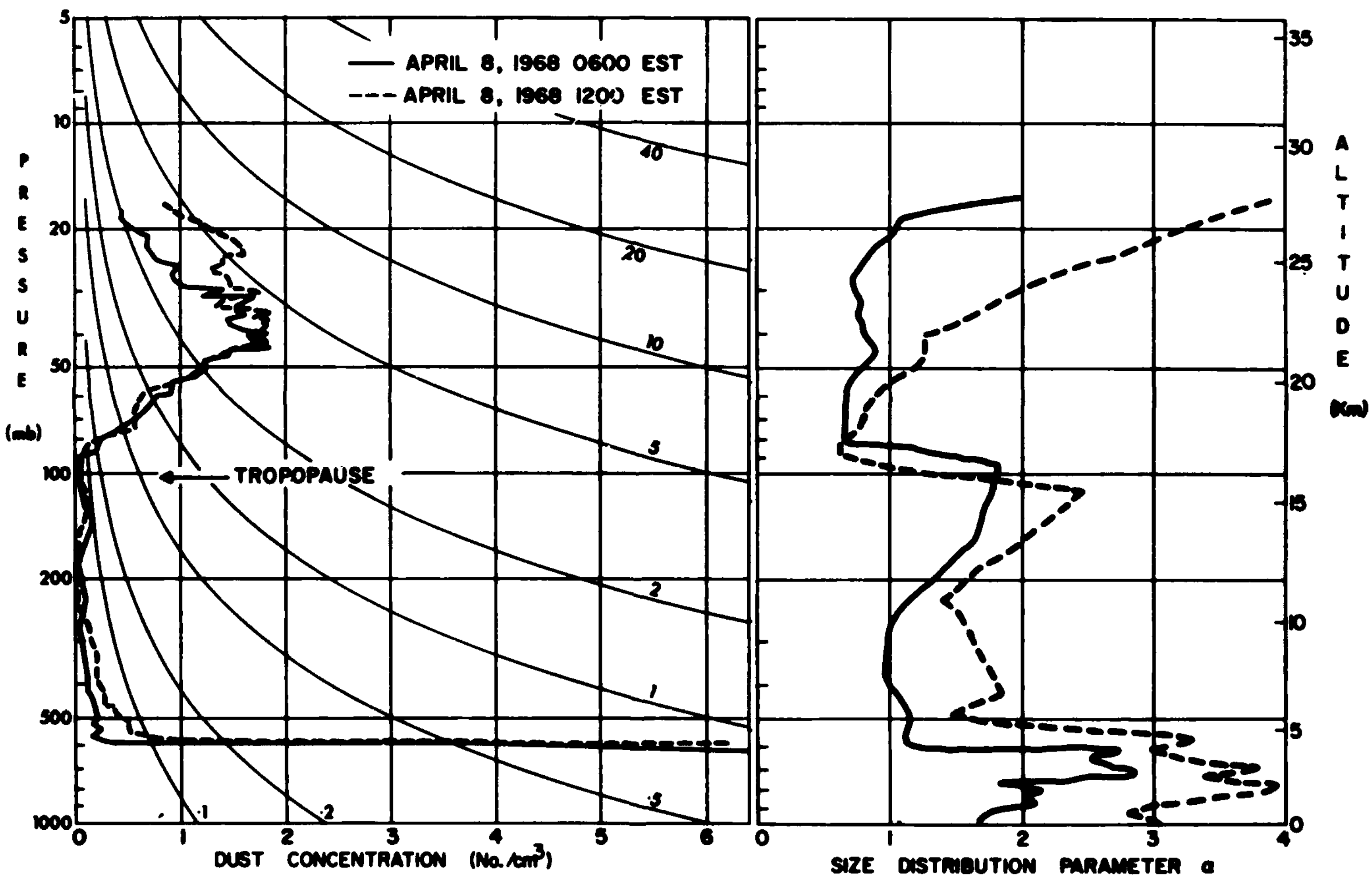

APRIL 8, 1968 0600 EST
APRIL 8, 1968 1200 EST
PRESSURE (mb)
5
10
20
50
100
200
500
1000
TROPOPAUSE
40
20
10
5
2
1
.5
.2
.1
0
1
2
3
4
5
6
DUST CONCENTRATION (No./cm³)
0
1
2
3
4
SIZE DISTRIBUTION PARAMETER α
ALTITUDE (Km)
35
30
25
20
15
10
5
0

Figure 4

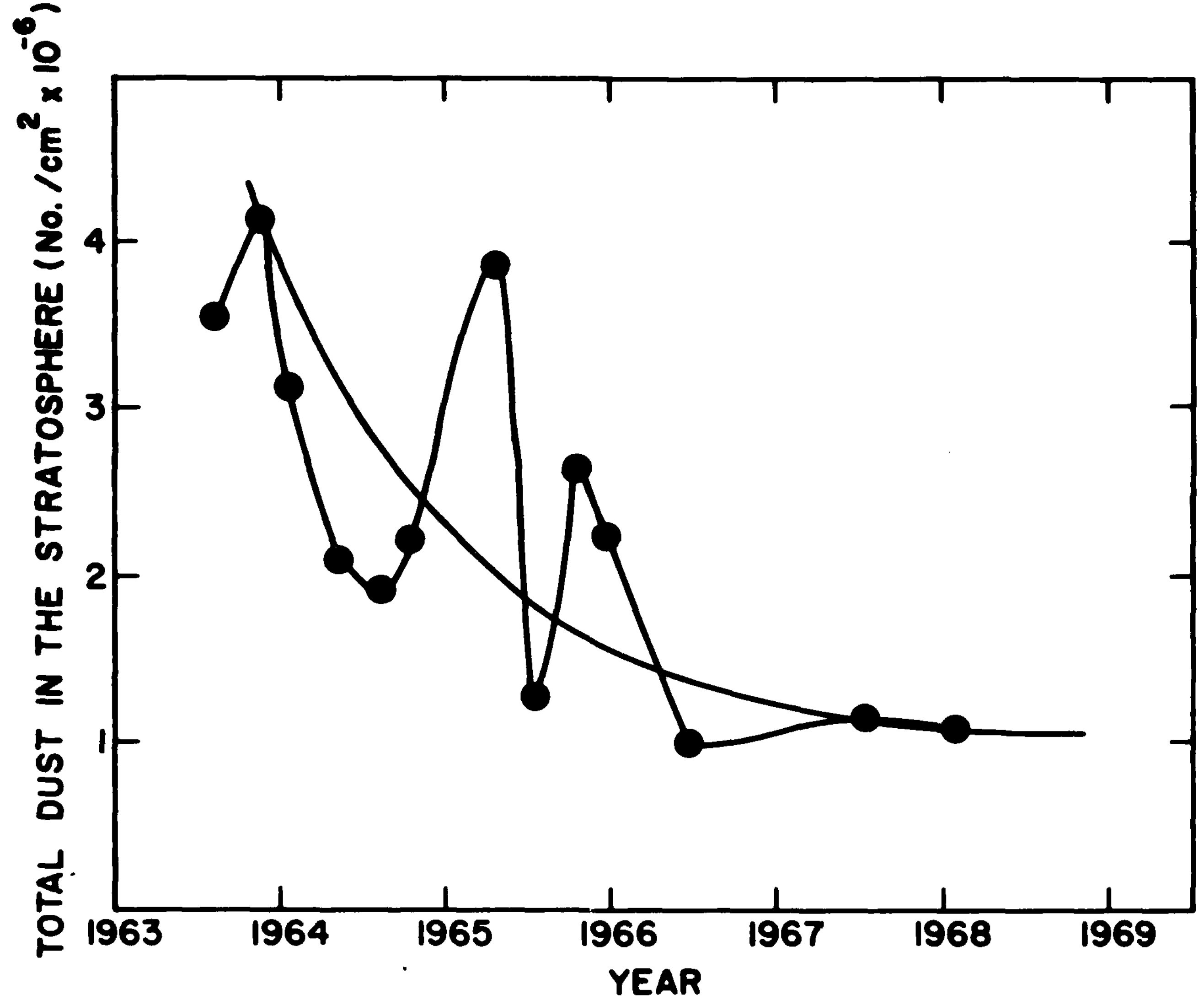
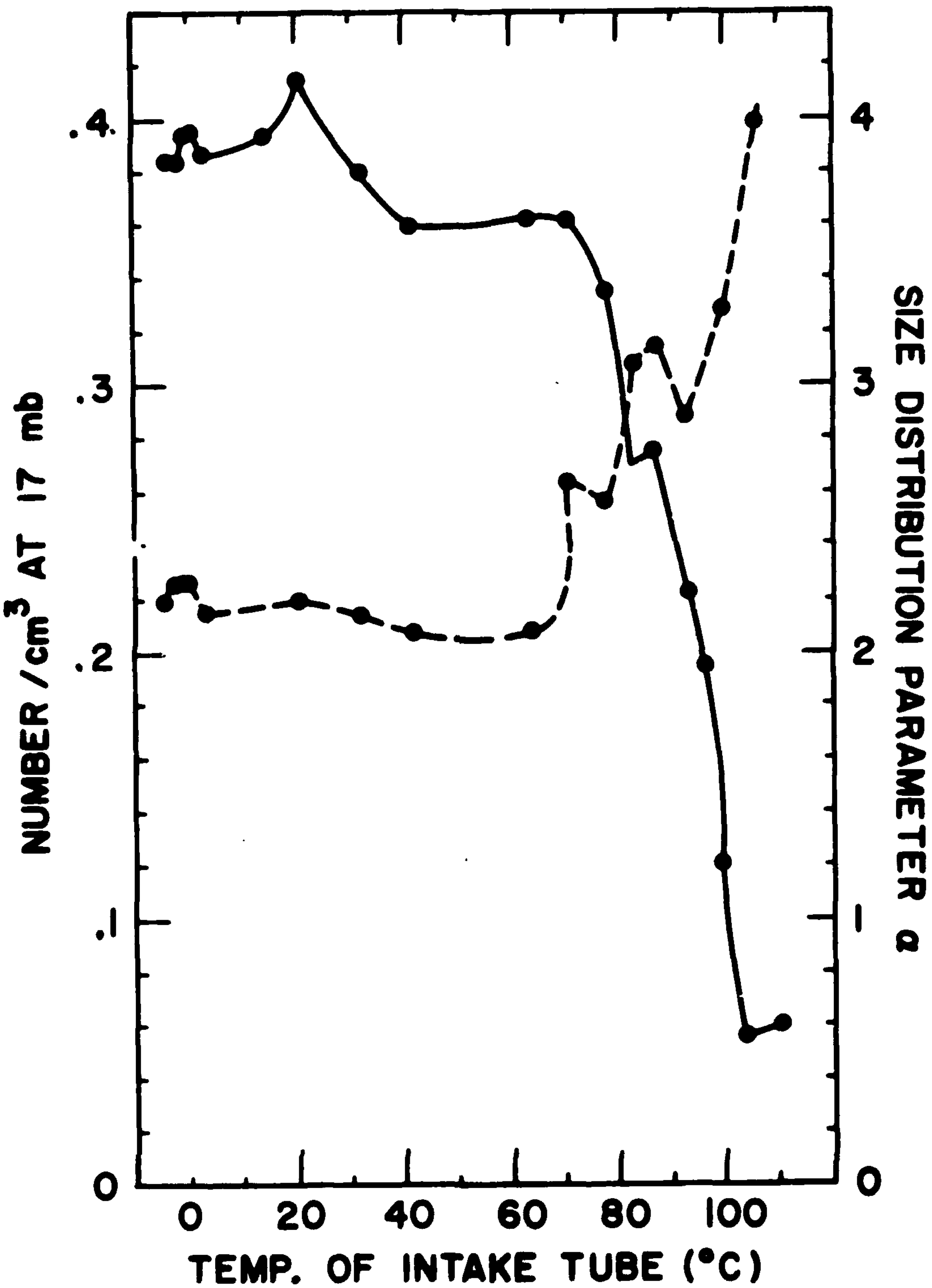

TOTAL DUST IN THE STRATOSPHERE (No./cm^2 x 10^{-6})
4
3
2
1
1963
1964
1965
1966
1967
1968
1969
YEAR

Figure 5



NUMBER /cm³ AT 17 mb
SIZE DISTRIBUTION PARAMETER α
TEMP. OF INTAKE TUBE (°C)
0
.1
.2
.3
.4
0
1
2
3
4
0
20
40
60
80
100

Figure 6

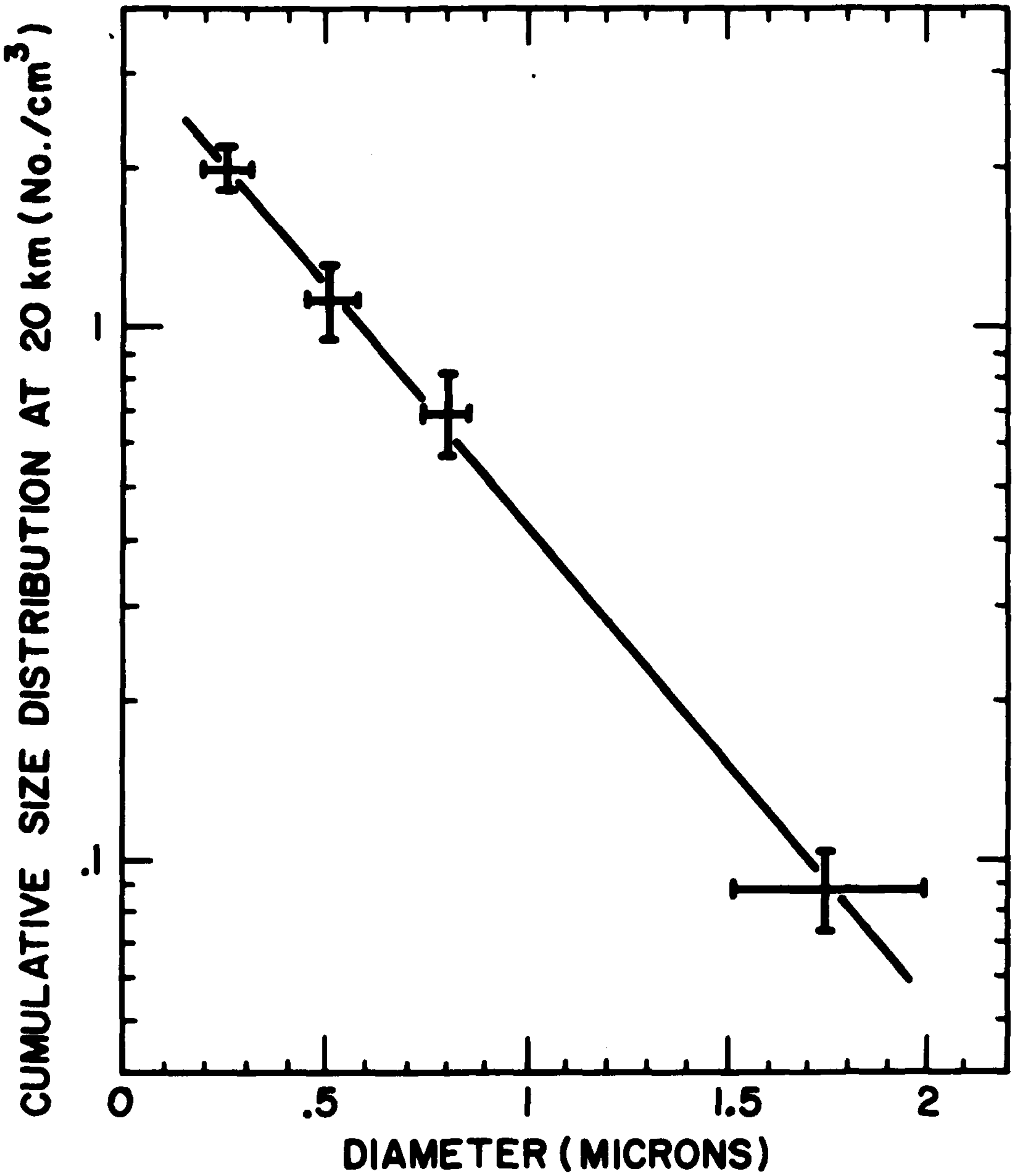

CUMULATIVE SIZE DISTRIBUTION AT 20 km (No./cm³)
1
.1
0
.5
1
1.5
2
DIAMETER (MICRONS)

Figure 5

Security Classification

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13. ABSTRACT

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